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Author(s): Thompson, Darla Graff
Woznick, Caitlin Savanna
DeLuca, Racci

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Spherical Platen versus Flat Platens in Compression Testing of PBX 9502

Darla Graff Thompson, Caitlin Woznick, Racci DeLuca
M-7, High Explosives Science and Technology, Los Alamos National Laboratory
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For ~15 years and perhaps longer, Pantex Plant has used a spherical platen in their compression load train when performing compression tests for Core Surveillance and HE Qualification. As our mechanical testing team at Los Alamos National Laboratory has always worked closely with our Pantex colleagues, and has maintained very similar practices in terms of calibration and testing, the author of this report has documented discussions with Pantex personnel (Robert Spence, et al.) dating back to ~2003, discussing the pros and cons of spherical platen use. LANL used spherical platens for a year or two, but determined issues and discontinued the practice. Based on multiple Engineering Evaluations (EE), LANL opportunities to watch Pantex procedures, it is our understanding that Pantex continued to use spherical platens from circa 2003 (or earlier) through summer 2019, despite the discontinued practice at LANL and the strong encouragement from LANL that spherical platens introduced error and should not be used. The short study reported here was intended to provide quantitative argument as to why spherical platens should not be used. As of a mechanical testing EE in August 2019, and after the testing of this LANL study was complete, LANL was informed by Pantex personnel that the practice of using spherical platens had recently been discontinued with no obvious problems or changes to the quality of the data. Although the urgency is gone for reporting our results, this is a brief quick summary of the data we collected.

Figure 1 shows the Pantex drawing of the spherical platen, hardened to RC 45-50. Note the shallow radius of curvature (2 inch). This platen sits atop the compression specimen and allows a point load from the upper rod to be equally distributed across the top surface of the specimen. The "pro" of the spherical platen is that it accounts for non-parallel surfaces in the load train and makes the initial loading very smooth. The "con" is that the point load allows the entire load train to have a bending moment at that point; as the load is increased, the compression specimen is allowed to bend, with the spherical platen rotating to accommodate. We will demonstrate these points with the data.

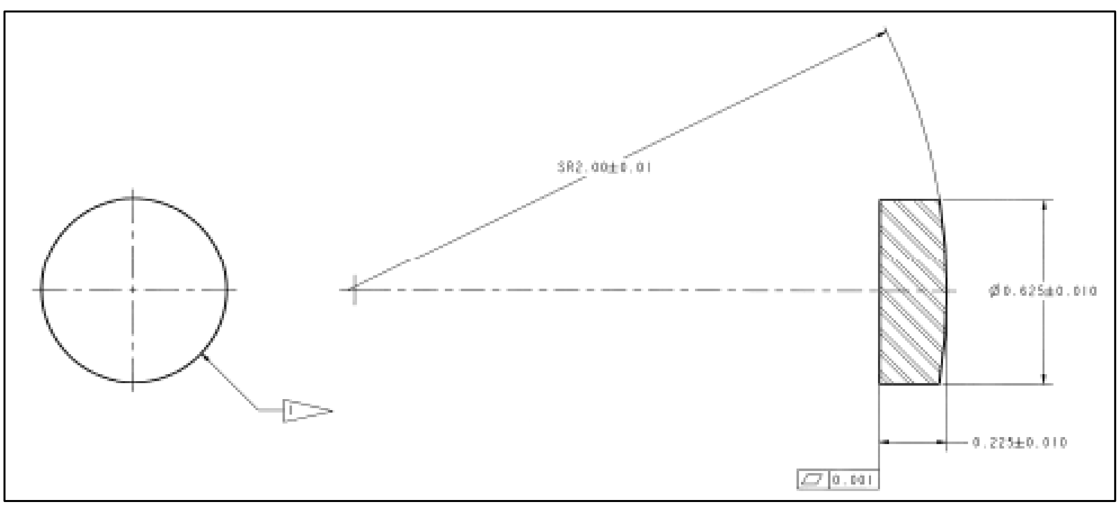

Figure 1: Drawing of the Pantex spherical platen used in this study.

Ten compression specimens (1-inch long, 0.5-inch diameter) were machined from transverse cores removed from isostatically-pressed hemispheres of PBX 9502, lot 891-009. Immersion densities were obtained on the specimens and they were divided into two equivalent groups. Compression tests were performed on an Instron 5567 with an attached Bemco Environmental Chamber. Two oppositely-mounted knife-edge extensometers were used to measure strain. Five specimens were tested using the spherical platen shown in Figure 1 and five were tested without, using only flat platens.

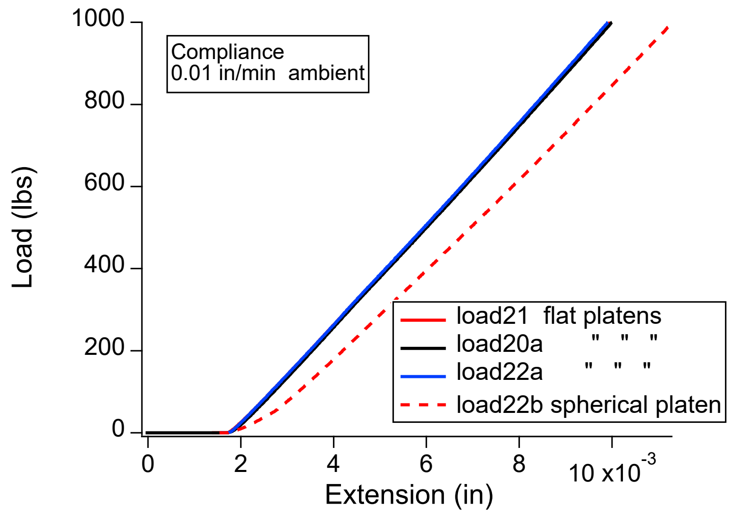

Figure 2: Compliance of the Instron load train with flat platens (solid lines) and with the spherical platen (dashed line).

An important part of the data is simply a comparison of the Instron compliance with no compression specimen mounted. In general, a stiffer machine, lower compliance, is desired, however, if tests are run in strain rate control with feedback from the extensometers, as is typically done in surveillance testing, then machine compliance does not likely affect the data. When only flat platens are loaded, the load train is restricted to uniaxial motion, and its stiffness is recorded and plotted as load versus extension in Figure 2. When the spherical platen is introduced into the load train, it provides a bending moment, and the stiffness of the load frame is reduced. Many physical adjustments were made in an attempt to improve the Instron alignment, etc.; the data in Figure 2 are representative of the best that could be achieved.

In Figure 3 are plotted the raw stress-strain curves for tests with flat platens only (left) and for tests using the spherical platen (right). In these plots, the red and green lines are the strain output of extensometer 1 and extensometer 2, the black line is the average strain calculated from the two extensometers. We immediately see a significant difference in the strain 1 and strain 2 outputs, caused by the introduction of a bending moment to the compression test. In the presence of the spherical platen, the radial alignment of the oppositely-mounted extensometers may be in or out of line with the maximum bending moment, and so the differences in the two strain readings can vary greatly. They will typically read equal and opposite, having a canceling effect when the average is calculated.

PBX compression data is typically analyzed using the average strain where the explicit bending information from the two extensometer is lost. In Figure 4 are plotted the stress versus average strain curves comparing flat and spherical platens. Here we see that the overall effect of the spherical platen is slight. The modulus (slope of the rising edge) at higher stresses shows some variation and spread in the spherical platen data. This error arises from the specimen bending as it is captured by the extensometers and averaged. We might also expect to see that the spherical platen gives rise to lower overall strength and a more brittle failure, if the bending moment has played a significant role in the failure. In these data, the effect is minimal, suggesting good flatness and parallelism in the load train and compression specimens (HE machining requests are for flat and parallel ends to +/- 0.001 inches).

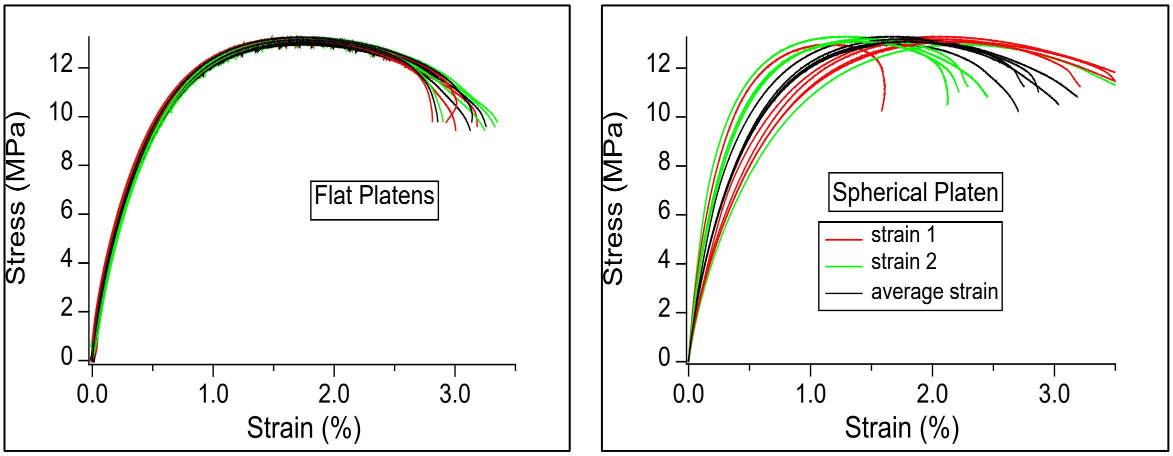

Figure 3: Raw stress-strain curves for all the PBX 9502 compression tests, using flat platens only (left) or using the spherical platen (right).

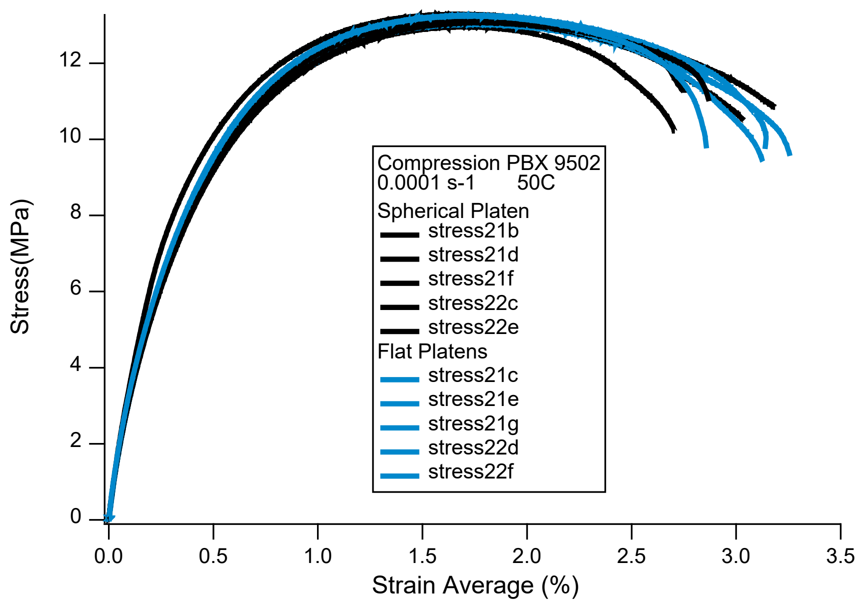

Figure 4: Raw stress versus average strain for the compression tests in Figure 3. See legend.

In Figure 5, we plot the load versus extension curves for the compression tests, zooming in to the low load region (left) and the high load region (right). In the low load region, we clearly see the benefit of the spherical platen as it was described above--- the point load accommodates any non-parallelism in the specimen and load train, so the initial loading is the same for every specimen. For flat platens, this “toe-in” region is a known phenomenon and discussed in related ASTM standards. The slight differences of load-extension compliance are due to the loading up of non-parallel surfaces and they “disappear” as higher loads are applied. In the high-load region of Figure 5, we see higher variability in the tests that used spherical platens. This is because some tests fail with a stronger bending moment than others, giving rise to (1) lower failure loads and (2) more brittle failure (load loss after failure).

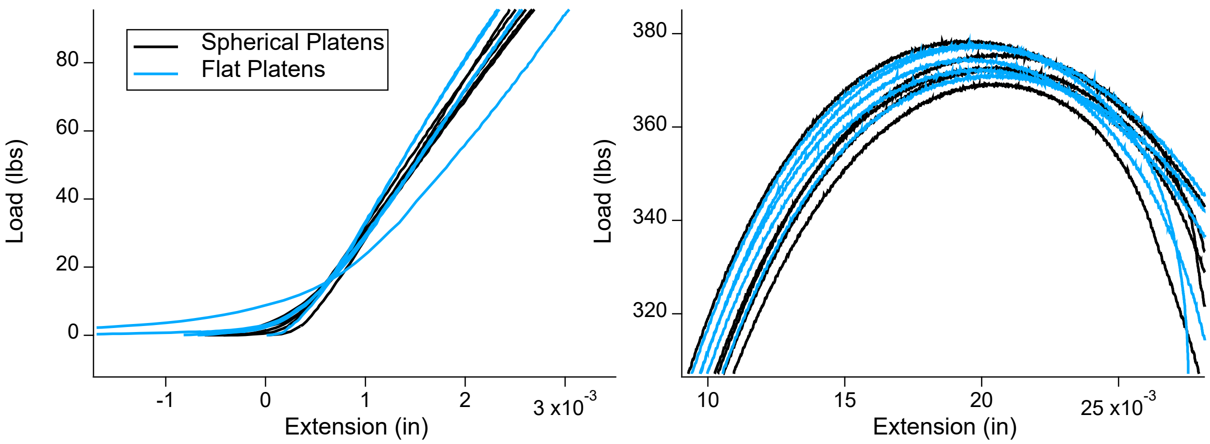

Figure 5: Zoomed in regions of the load versus extension curves for the tests in Figures 2 through 4, low load (left) and high load (right).

In Figure 6, we plot the three compression parameters of Stress Max, Average Strain at Stress Max, and the Modulus (slope) at 50% of Stress Max--- each versus the specimen density. These parameters are taken from the data plotted in Figure 4. In Table 1 are listed the averages (standard deviation in parentheses) of these three parameters and the densities. Although we have pointed out some of the consequences of using a spherical platen, with this limited data set we conclude that the average compressive parameters are not statistically changed by the use of a spherical platen. We conclude that best practices probably are to NOT use spherical platens, however, we believe that with regard to PBX compression measurements (in Core surveillance over the years, and for the year or two that the practice was implemented by us at LANL), likely there are not significant errors in the measured properties due to spherical platen use.

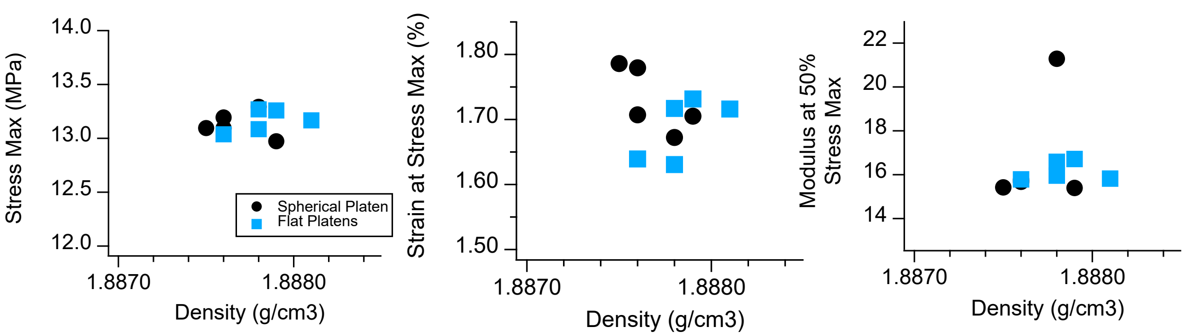

Figure 6: Compression parameters plotted versus specimen density for tests with spherical platens (black symbols) and tests with flat platens (blue symbols).

Table 1: Average Compression Parameter Values (with Standard Deviations)

Compression Parameters	Spherical Platen	Flat Platens
Stress Max (MPa)	13.13 (0.12)	13.16 (0.10)
Strain at Stress Max (%)	1.730 (0.050)	1.687 (0.048)
Modulus at 50% Stress Max (MPa/%)	16.71 (2.56)	16.18 (0.44)
Density (g/cm3)	1.8877 (0.0002)	1.8878 (0.0002)